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PACKET RADIO ISSUES - II

In this note, we continue our discussion of issues related to the packet radio system development. Three of the topics which are discussed in this memorandum - uniform accessibility, power sources and signaling and fault detection involve a large number of open questions that remain to be answered. Two of the topics - a separate station and a compact repeater are not really issues any longer but rather specific design guidelines.

1. Power Sources - The "initial" radio system experiments can be adequately powered with electricity from lead storage batteries or from the local power company. Shortly thereafter, though, we will need to provide other effective power sources for both repeaters and for terminals. Some observations about possible power sources are given below. For further reading, a good reference is "The Primary Battery", edited by George W. Herse and N. Corey Cahoon, John Wiley and Sons, New York, 1971.

The following target objectives for the terminal power source seem appropriate:

20 watts peak power
5 hours continuous operation (100% duty cycle)

1 pound approximate weight
5 watts average power dissipated

With a duty cycle of .01, the battery should last 500 hours, or 20 days without recharging or replacement. In terms of energy density, this requires a 25 watt-hour/# battery.

The following target objectives for the repeater power source seem appropriate:

50 watts peak power
2 month continuous operation (100% duty cycle)
100 pounds approximate weight
10 watts average dissipated power

With a duty cycle of .20, the battery should last about 10 months without recharging or replacement. In terms of energy density, this requires a 72 watt-hours/# battery.

Possible initial candidates for the repeater include lead acid batteries, Nickel Zinc, Nickel Cadmium, Silver Zinc, or Hydrogen fuel cells. The last two items have particularly attractive attributes. Possible initial choices for the terminals include Nickel Cadmium and alkaline (Dura)cells.

A few additional observations - It is possible to produce 100-200 watt-hour/# batteries with sodium sulphur and lithium sulphur now under development. However, these batteries become quite hot from chemical reactions (e.g. 300 C). Silver Zinc batteries appear to have the highest energy densities of commercially available products and are used by the Navy. A typical Silver Zinc cell is rated at 4000 amp-hours which is 35 watt-hours/# for a 165 pound

1.5 volt cell (size 10" by 10" by 20"). Because of their low power, unreliability, and/or cost, miniaturized nuclear batteries and solar cells seem to be inappropriate candidates for the packet radio experiment, but thermo- nuclear generators may eventually be useful for powering repeaters.

2. Uniform Accessibility - A packet radio repeater is expected to cover an area many miles in diameter, and terminals will be located at various distances one or more repeaters away from the station. A terminal which is able to communicate with a repeater should be able to obtain the same nominal system performance as any other "similar" terminal independent of its location in the local radio system. Other things being equal, a change in the distance of a terminal from the station should not result in substantially changed performance (delay, throughput, reliability etc.).

It desireable to define a region called the "broadcast region" of the radio system in which terminal communications with the station is assured and outside of which performance is not guaranteed. When the capacity of the broadcast region has been exceeded (as Abramson has shown THE PERFORMANCE is a function of distance from the station in a slotted ALOHA system with capture) additional stations will be introduced. Thus it is more natural to define the "broadcast region" by received

signal to noise power ratio rather than by offered traffic. A simple criterion for our purpose is to select the region to include all points where the received signal to noise ratio is 10db. or larger relative to the average background noise. Impulse noise may ultimately prove to be the determining factor, but it is proposed that we ignore it for the moment.

3. Compact Repeaters - It is expected that repeater locations will typically be outdoors and elevated. For these devices to be effectively positioned atop poles, towers, placed on the ground or buried (the electronics not the antenna), both a rugged structure and an all weather housing is required. A target packaged size (without power) no larger than a 1-1/2 foot cube is initially desireable for these requirements to be met and the digital logic must be tightly incorporated into the repeater. A built-in microprocessor can effectively satisfy this objective. With current technology, a separate mini-computer (while more powerful than the microprocessor) is also considerably more difficult to engineer that way.

4. Separate Station - The station attaches via a communication circuit to one (or more) repeaters and provides a point of entry or departure for all traffic to or from the packet radio net. The station may be housed in any convenient location and, in particular, need not be

co-located with its repeater(s). Even if co-located, it need not be held to any definite prescribed minimum distance. It is desireable that the station be built around a mini-computer and that it perform as an operating system front end; in particular the station would have the form of a stripped down version of an operating system with no user computational capacity, no mass storage, no active file system (although perhaps a latent one) and a human engineered user interface. This approach makes it possible to achieve the appearance of a packet radio system as part of one large resource complex, even though the resources happen to be widely distributed.

5. Signalling and Fault Detection - Remote diagnosis of repeater, station, and terminal failures is an essential requirement for the packet radio system. Diagnostic capabilities must be available for the user as well as for system maintenance personnel, testing and debugging. The user must be able to verify in a simple way and without assistance whether a failure is due to his terminal or to the rest of the packet radio system. This can be achieved with a set of signaling strategies which may also allow the point of failure to be uncovered in certain cases. When all is working properly, each active component of the system is in communication with some other active component. Nominally, the station is in communication with one or more termim ls, the terminals with the station, the repeaters with the station and other

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repeaters. If any one or more of these components should fail, another one should detect it. In certain cases, it will even be desireable to try to activate a failed repeater remotely, but probably not to try to reactivate a station or a terminal remotely.

a. Terminal - The terminal has both a local and a remote mode, with the remote mode being the usual on-line mode of operation. In local mode, the user can check the battery and verify that the unit appears to be operating properly. In remote mode, the user can verify whether the station is listening and whether he can talk to it.

We assume that the terminal has an on/off switch and a single light* normally on to indicate clear to send. The station sends out a breadcast signal (packet) to all repeaters in its region every second, somewhat like a pilot carrier. When the terminal finally receives this packet, it will "reset" the light on for say 5-10 seconds, after which time it will go off unless one or more packets were received in the interim. This provides a steady signal to the user that indicates a path from the station to the terminal. The user gets to test the path to the station by sending packets. If his packets are not echowed at the terminal, he can safely assume that the packets are not

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* After having carefully considered using multiple lights on the terminal (e.g. power, buffer overflow, station, clear to send etc.), it was concluded that a single light was sufficient for the user and least confusing. The possibility of no lights was also considered and rejected.

reaching the station (provided the light stays on) and therefore that there is no operable path to the station among all other repeaters.

b. Repeater - Various signals can be measured at the repeater either by direct connection during testing, maintenance and debugging or by transmission or remotely by the transmission of special packets not generally available to normal users. No lights or signals are visually observaibe at the repeater. Internal switches in the repeater allow it to be turned on and off smoothly without the loss of packets, but the on/off procedure is to be protected; a lock and key arrangement would be initially satisfactory. While the station normally connects to the repeater via a communication circuit (however short) an auxiliary pair of jack connections to the repeater allows test packets (special packets) to be entered and received by wire for local testing. One jack connection turns off the RF, the other is used for monitoring and does not. Ultimately the monitoring capability may be removed.

The special packets cause the following types of action to occur:

. the test packet to be discarded
. the test packet to be returned
. the contents of memory to be returned
. the contents of memory to be reloaded
. the repeater to be restarted
. [illegible]

Other test and measurement facilities and features are desireable in the final unit, but are deferred in this discussion.

c. Station - The station must assume the lions share of the responsibility for managing the fault detection and signalling strategy. It must be able to locate a failed repeater in a field of repeaters. Let us assume that each repeater broadcasts ID messages to the station every minute or so. The station keeps track of the sequence of repeaters to use to reach each active terminal, which it includes as part of the terminals address. When a repeater goes down, the station learns within a minute. When it can no longer reach a terminal with the old routing, it modifies the routing, if possible, or else declares the terminal to be disconnected. If the repeater is declared down, all active routes involving the repeater will be recomputed by the station. If a message does not get acknowledged, and the repeater chain is not understood by the terminal to be inoperative, the station will time-out and resend the message, or conversely, the terminal will time-out and resend the message. Throughout the system end-to end sequencing is used to discard duplicates and to insure proper flow control.

$1\ min = \frac{60 \times 10^6}{10^3}\ b.h = 60\ msgs/sec$